THE ECOLOGY OF SUGARLOAF BUSH, CASS.

II. TEMPERATURE MEASUREMENTS

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ABSTRACT

The paper describes temperature measurements taken with maximum/minimum thermometers, at monthly intervals, in contrasting sites within and outside the forest, from December 1977 to June 1982. The temperature extremes so recorded allow the temperature regimes of the sites to be broadly characterized and thus provide useful background for further ecological study.

KEYWORDS: forest, temperature, maxima, minima, contrasting sites.

INTRODUCTION

The ecology of even as simple a plant community as mono-specific mountain beech *(Nothofagus solandri* var. *cliffortioides)* forest is, nevertheless, complex. The basic ecology of the species is reasonably well known (cf. Wardle 1970a, b, c, d; Burrows 1977) but much remains to be done. Forest Service scientists are continuing studies on the climate relationships, ecophysiology, production ecology, soils and ecosystem nutrient budget for the species in the Craigieburn Range forests (14 km south of Cass). University scientists have done some basic work on the light climate in the forest at Cass (Stevenson 1981) and in the Craigieburn Range (Turton, 1982).

This paper records some simple temperature measurements, made as part of the ongoing study of Sugarloaf Bush (Fig. 1). The study sites (Fig. 2) were selected to represent the contrasting aspects on a profile across the Sugarloaf Bush Valley and also some differences in vegetation cover. Most are within the forest perimeter but five sites lie outside it (Table 1). Generally, within the forest, the shaded (south-to-east facing) aspect has an almost continuous cover of young understorey beech trees.

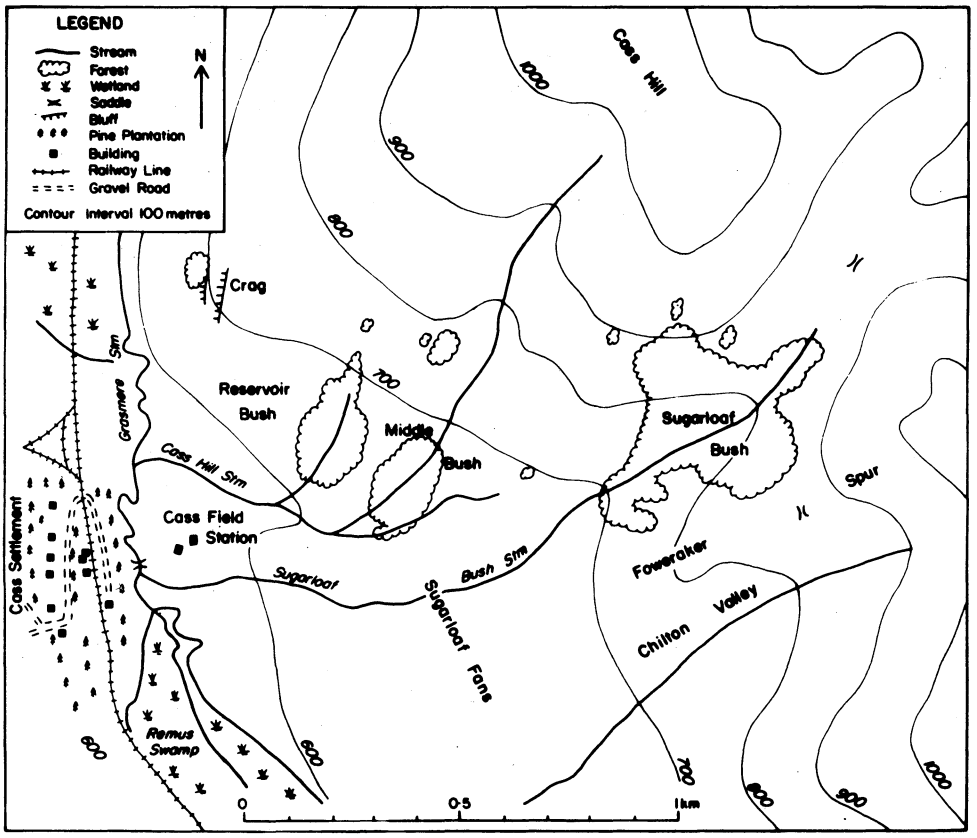

Fig. 1. Sugarloaf Bush and places in its vicinity.

The sunny (north-to-west facing) aspect has some patches of young trees, but also extensive areas lacking them.

The details of instrumentation at each site and periods of exposure are listed in Table 1. Zeal maximum/minimum thermometers were used. All were calibrated against standards over a range of temperatures, before and after being placed in the field. Any instruments which did not agree with the standards by better than ± 0.5°C were rejected.

The mode of exposure of all thermometers except those at ground level and those at 1.5 m above the ground, outside the forest, was for them to be screwed to the southern side of a tree with the scale upright. Outside the forest thermometers at 1.5 m were screened from direct radiation by being placed on the south side of an upright board 30 cm long x 10 cm wide x 2 cm thick, painted white and fixed to a guyed "Waratah" standard. The ground thermometers were each laid horizontal and screened by a wooden board of the same dimensions, held by wire legs about 5 cm above the thermometer.

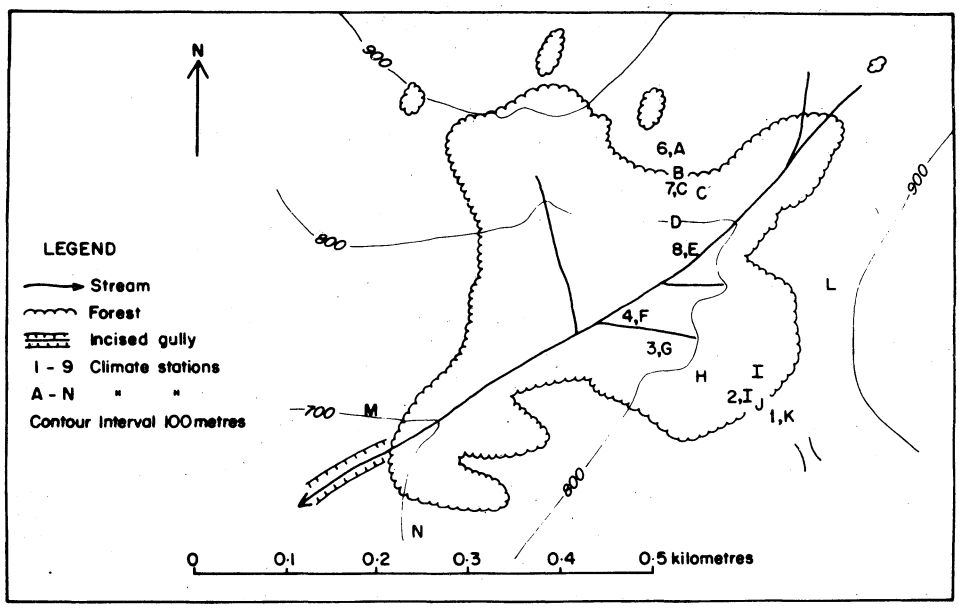

Fig. 2. Sugarloaf Bush showing the location of stations for temperature measurements.

The thermometers were read at monthly intervals, as near to the beginning of each month as possible. Various breakages, disappearances and general disturbances of thermometers occurred, some caused by wind and some probably by brush-tailed possums. Human interference (the culprit was never identified) was probably responsible for a long bout of disturbance in 1980. In these instances some of the missing data can be interpolated from adjacent sites. Instrumentation was changed after a preliminary first run December 1977 - August 1979. Some new sites were established, also, for the second run.

RESULTS

The results of the thermometer runs are presented in two series (Table 1, Fig. 2 and Figs. 3-9). Data from only a few sites are presented; these were found to be representative of site types. All of the raw data are held on file by C.J.B.

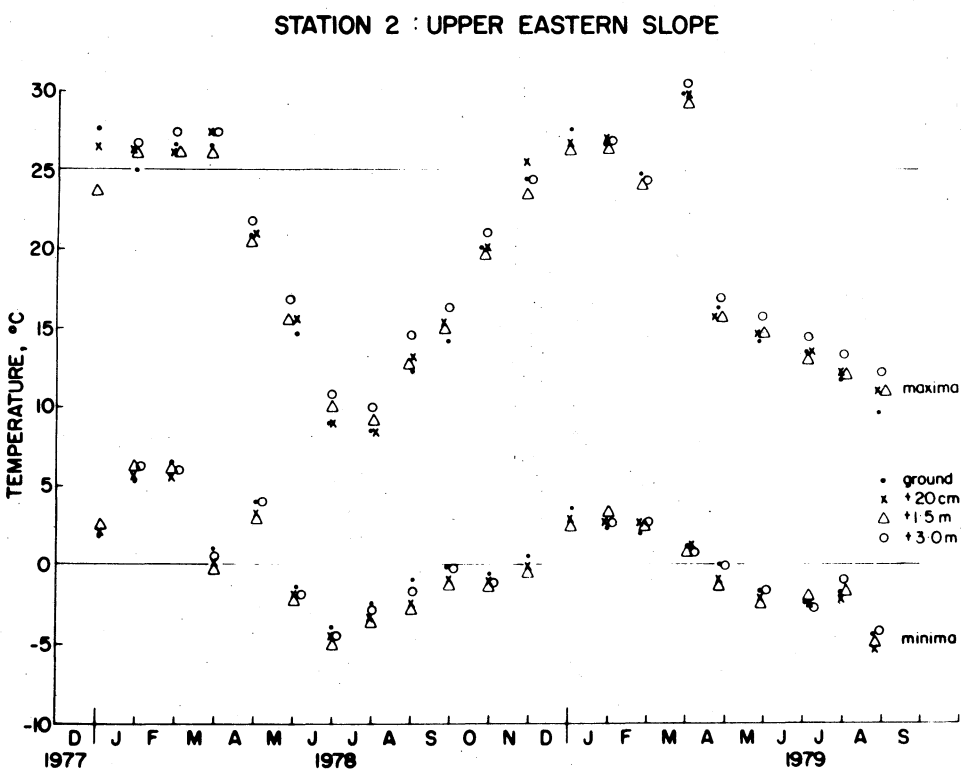

Fig. 3. Run 1. Extreme values recorded for temperatures at Station 2. (Each of Figs 4-9 depict similar information).

FIRST RUN DECEMBER 1977 - SEPTEMBER 1979

I. *WITHIN THE FOREST*

Station 2; Upper Eastern Slope

Extreme minima fluctuated from about -4.5°C (winter) to +6° C (summer). There was little difference between the minima for the four heights, relative to ground level, which were examined. There was a relatively even minimum air temperature in the forest and it was not markedly cold. Extreme maxima varied from +8°C (winter) to +30°C (summer). Slightly more temperature stratification was evident, with the +3 m above ground level values often being about 1°C higher than those nearer the ground.

Station 7; Upper Western Slope

Extreme minima were virtually identical with those of the eastern slope. Extreme maxima frequently were lower than those

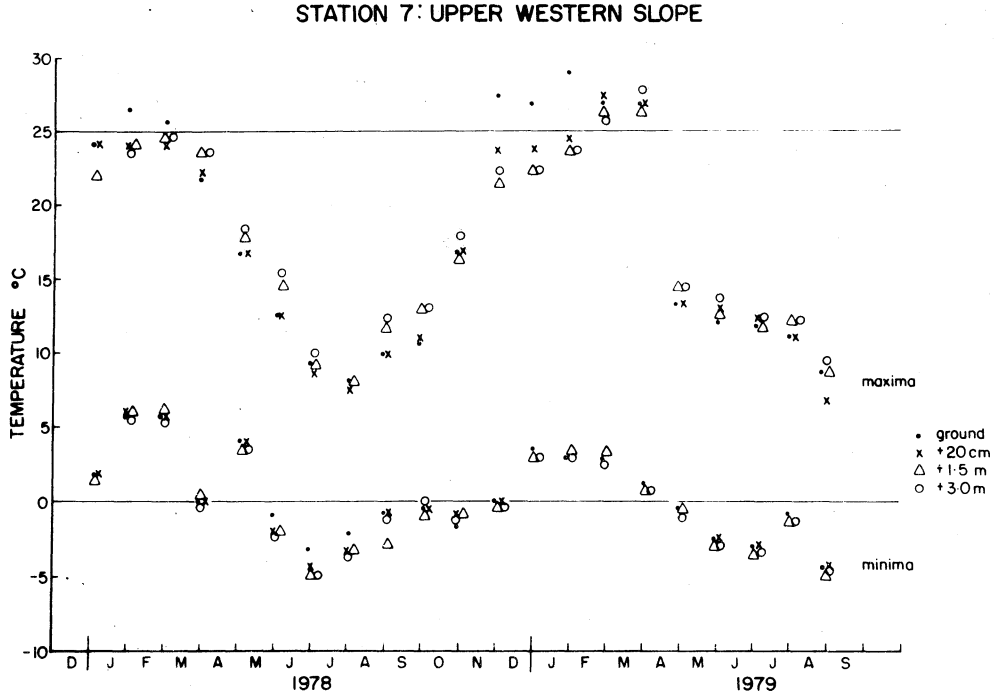

Fig. 4. Run 1. Station 7.

of the eastern slope by 0.5° to 3.0°C, especially in summer. Ground temperatures were often higher than those at other levels during the summer, otherwise the pattern of stratification is also similar to that on the eastern slope.

General

All other sites on sunny and shady aspects in the forest had similar temperature regimes to those of Station 2 and Station 7, respectively, during the period of recording.

II. *OUTSIDE THE FOREST*

Station 1; East Saddle

Extreme minima (at ground level only) ranged from -4°C (winter) to +5.5°C (summer). Both in winter and summer, they were often lower by 0.5° to 1°C than the ground temperatures within the forest. The outstanding difference between this site and those in the forest, however, is the very high maxima attained here in summer. A range from +8°C to +36°C is experienced from winter to summer, thus the winter maxima are lower than those in the forest by 0.5° to 1°C but the summer maxima are usually more than 5°C higher

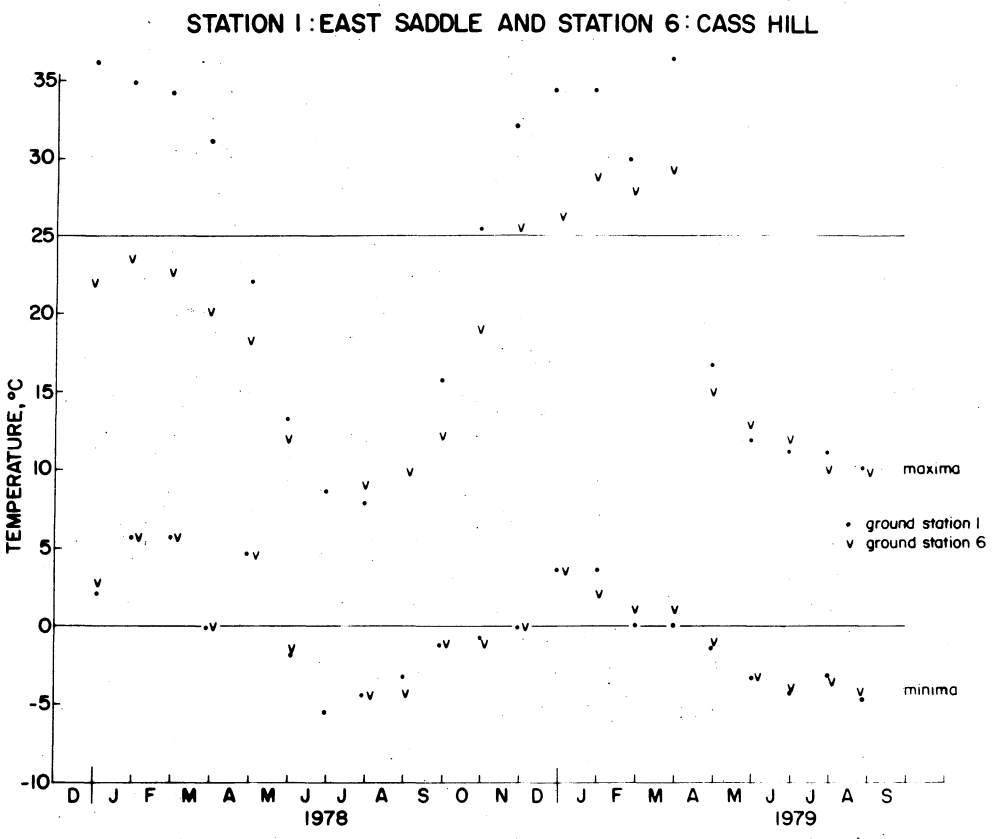

Fig. 5. Run 1. Stations 1 and 6.

and sometimes 7°C or more higher. These high temperatures, as recorded, may in part be a result of strong radiative heating of the thermometer beneath its wooden screen. However they reflect the potential for strong heating near the ground on sunny aspects where no forest canopy intercepts the full force of radiation. In fact they are very similar to extremes measured with thermistors in the nearby Chilton Valley (Greenland 1977). Bare ground and stones on such sites will be very strongly heated.

Station 6; Cass Hill

In this shady site extreme minima were almost identical with those on the sunny eastern slope. Extreme maxima however differed considerably. They ranged from +9.5°C to 29°C but in 1978 only reached 23.5°C. In 1978 the summer maxima were often lower than those within the forest but were consistently higher than in the summer of 1979.

General

The sites in scrub vegetation, with patches of short turf or bare ground, have temperature regimes contrasting with those of the forested sites mainly in the greater extremes experienced. A noteable feature of records at each site inside and outside the forest is the very sharp drop in temperature during April 1979. There was a similar, but not quite as spectacular fall in May 1978 and a marked rise, also in October - November 1979. As a result of verification that relatively little air temperature stratification was evident in the forest up to 3 m above the ground (possibly because of the windiness of the Cass climate) it was decided to record the next sequence only at +1.5 m above the ground and -20 cm below the ground surface. A few more sites were added.

SECOND RUN SEPTEMBER 1979 - JUNE 1982

III. *WITHIN THE FOREST*

Station I (Old Station 2) Upper Eastern Slope

Extreme minima at the 1.5 m level ranged from -4.5°C (winter) to +5°C (summer). Extreme maxima ranged from +10°C (winter) to +28°C (summer). The patterns have been very similar at this level for the four winters and five summers of recording.

In the soil, at -20 cm, temperatures never fell below freezing, the lowest minima were +0.5°C (winter) and 9°C (summer). Maxima varied from 6.5°C (winter) to 21°C (summer). Both these extremes were recorded in 1981 and in other years winter maxima were a little higher and summer maxima lower.

Station C (Old Station 7) Upper Western Slope

Extreme minima at 1.5 m were marginally lower than on the eastern slope, especially in summer. Extreme maxima were slightly lower in winter and often lower in summer by 1° - 2°C. Again the patterns have been similar, at this level, for four winters and five summers. In the soil, extreme minima were also marginally lower than those of the eastern slope, in summer. Extreme maxima, however, were almost always 1° - 3°C lower. Soil temperatures, thus, discriminate well between the contrasting aspects.

Satellite Stations to Stations I and C (Stations 1 and C).

Data from these thermometers, set out on the ground in contrasting cover conditions are not detailed here. Generally the results, especially those on the eastern slope, were variable, possibly because of changing disposition of sunflecks which affected the sites. A study of the solar radiation received beneath the canopy on the eastern slope of Sugarloaf Bush Valley, under similar variable cover conditions, (Stevenson 1981), showed considerable point

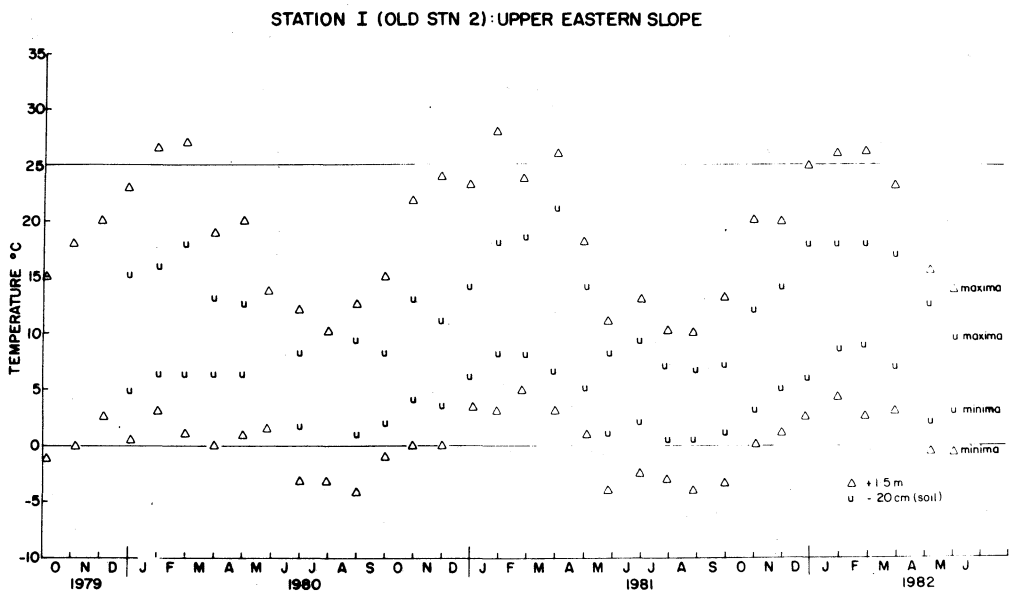

Fig. 6. Run 2. Station I.

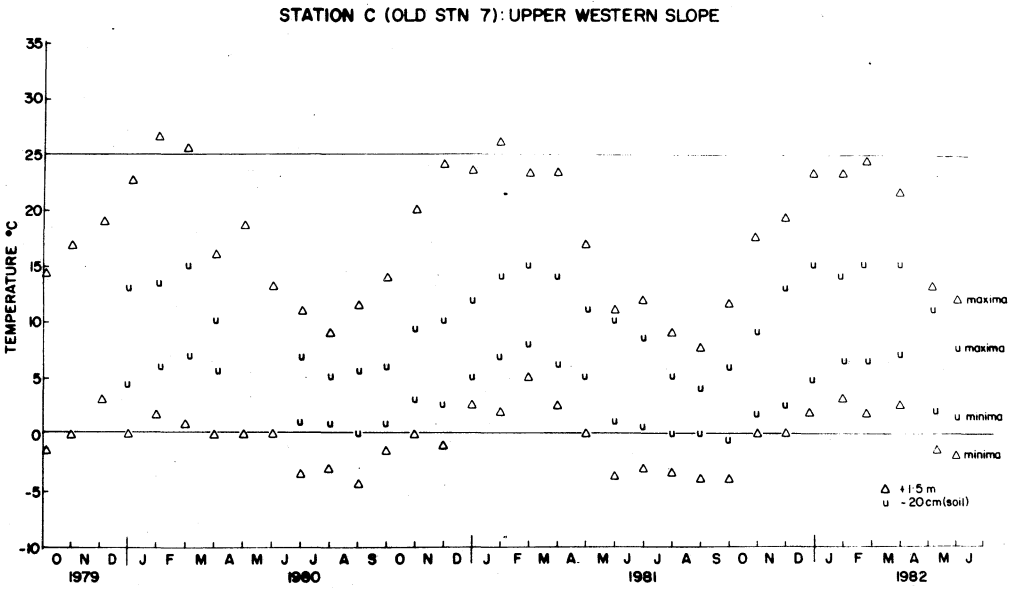

Fig. 7. Run 2. Station C.

variability which is attributable to the complexity of canopy architecture in relation to changes in the solar path. This has to be taken into account when siting equipment, which is not well screened, for temperature measurement. Windiness and consequent canopy movement is another complicating factor.

IV. OUTSIDE THE FOREST

Station K (Old Station 1); East Saddle

Extreme minima at the 1.5 m level ranged from -7°C (winter) to +3°C (summer). They are considerably lower, by 1° - 2°C than those in the forest. Extreme maxima ranged from +13°C (winter), to +36°C and these are considerably higher than the forest maxima, especially in summer. Strong heating is evident, as it was from the ground thermometer at this site in the previous run. The maxima in summer are frequently 5° to 7°C or more higher than those in the forest. In the soil at -20 cm the extreme minima are usually a little higher than those in the forest, especially in summer. The extreme maximum summer soil temperatures, ranging from +6°C to +25.5°C are usually higher than those in the forest, especially in summer, by 1° to 2°C or more.

Station A (Old Station 6) Cass Hill

Extreme minima, at 1.5 m ranged from -8.5°C (winter) (the lowest temperatures recorded at any site, during this study) to +2.5°C (summer). They were usually marginally lower than those at Station K, but 1° - 2°C lower than those in the forest. The extreme maxima ranged from +8°C (winter) to 30.5°C (summer) but were, in two summers out of three, only up to 28°C. In summer the maxima were usually higher than those in the forest by 1°C and sometimes 2°C higher. The shaded aspect outside the forest, however, is considerably cooler in summer than the sunny aspect.

General

During the second run the sharp fall of maximum temperature near the autumn equinox is apparent in most years. A sharp rise near the spring equinox also occurred in some years. Over the period of recording January and February were consistently the hottest months, but sometimes December and March were also hot. The coolest months were usually June and July, but often August and sometimes May and September were also cold. The second run tended to confirm the general temperature patterns established for the same sites during the first run. This is also true for the sites not described here in detail. At sites immediately at the forest edge (beneath the canopy of the outermost trees) the temperature regime is more like that of the forest, than that of the sites well outside it.

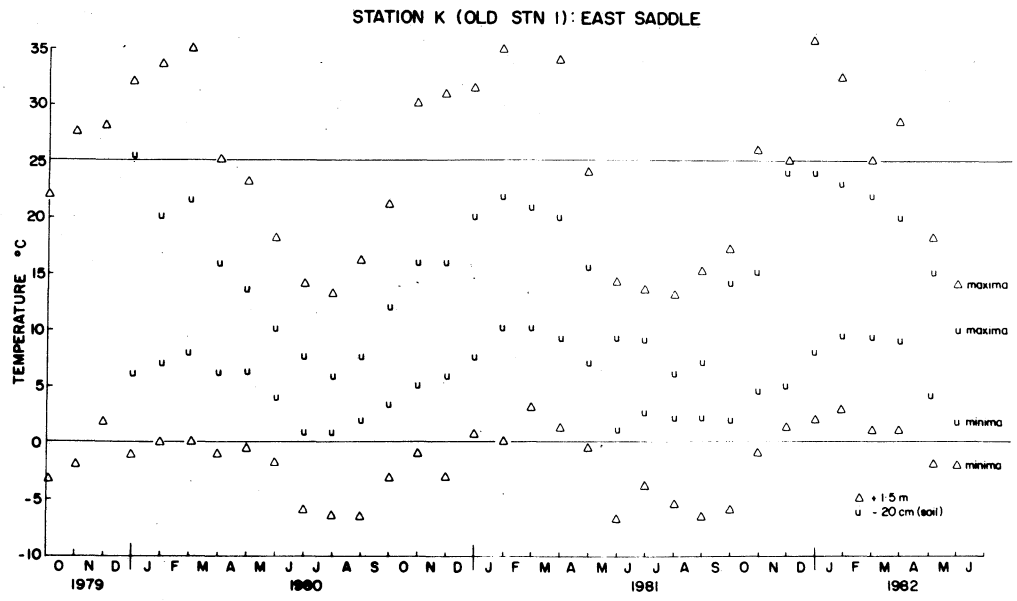

Fig. 8. Run 2. Station K.

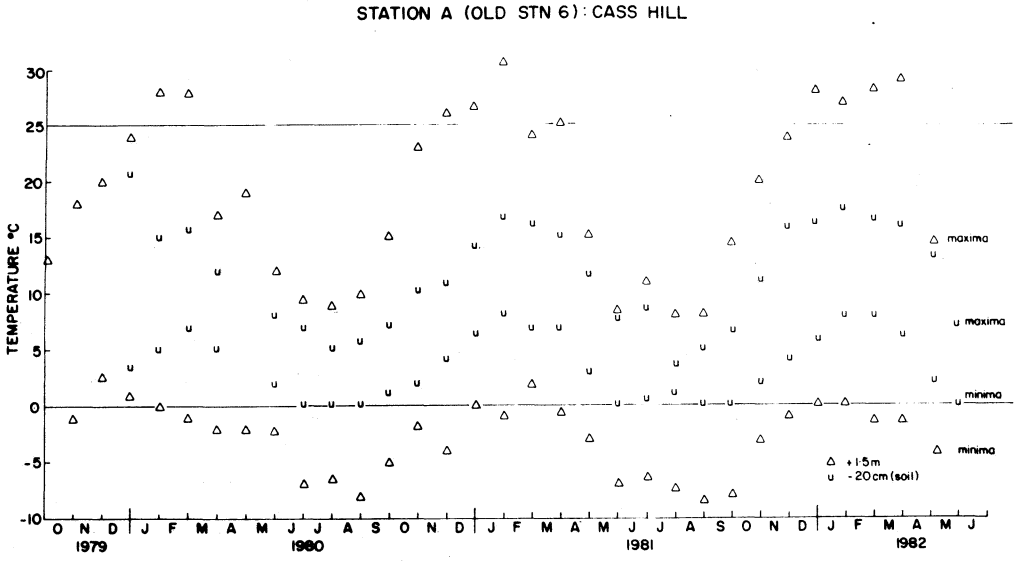

Fig. 9. Run 2. Station A.

DISCUSSION

The temperature data described show that the forest has a relatively mild climate, damped down at either extreme, compared with unforested sites. The patterns for the latter resemble those for corresponding sites in the adjacent Chilton Valley (Greenland 1977). Extreme minima in Sugarloaf Bush are not as severe as those which occur in the grassland site at the Cass Field Station. Extreme low temperatures to -16°C occur there at times and to about -12°C each winter. Winter maxima in the forest are low but summer maxima are relatively high. As Greenland (1977) points out, the Cass mean temperatures, in hillside sites, are lower than those of Christchurch, but nevertheless high for the altitude and the inland location.

It should be noted, with respect to the Sugarloaf Bush data, that the values obtained, although they will resemble the extremes measured at more sophisticated climate stations, are not to be equated with them because of the differences in instruments used, modes of exposure and frequency of measurement. $\frac{\text{Maximum + minimum values}}{2}$ will give only approximate mean values.

The data demonstrate the ameliorating effect of the forest on temperature regimes beneath the canopy, compared with those in unforested sites. The mild forest temperatures create favourable conditions for establishment of beech seedlings and growth of young plants. More severe winter conditions outside the forest may be a factor in limitation of seedling establishment, which rarely occurs beyond the forest margin. The forest shows signs of slow marginal spread, with ranks of young trees forming a band around its perimeter. More work is needed on specific temperature conditions limiting growth of juvenile and mature beech plants although Wardle (1971) has experimented with the effects of low temperature conditions on seedling survival in the field over a range of altitudes. Survival is related, by Wardle, to the need for a definite period of maturation before the plants can become hardened to low temperature. Otherwise the leafy shoots succumb to frost-induced winter desiccation. Periodic spring or early summer frosts (to -5°C or lower) can kill new (unhardened) shoots of juvenile and adult beech trees outside the forest margins, as has been observed several times at Cass (Burrows 1977). Adult trees are less susceptible than juveniles, however, because their growth flush starts later and is completed earlier (Wardle loc. cit.). Sakai, Paton and Wardle (1981) showed that tissues of mature, hardened mountain beech, collected in winter in the Craigieburn Range could survive low temperatures only down to -13°C (leaves, and -15°C (buds, cortex and xylem). The extreme minimum temperatures recorded so far outside the forest at Sugarloaf Bush do not approach these levels, but those at the Cass Field Station do. Norton (1982) shows that growth phenomena in the mature mountain beech trees in Sugarloaf Bush is, clearly, related to the temperature regime.

Whatever the effects of temperature on establishment of seedlings beyond the forest margin, competition with other plant

species, especially a dense turf of herbaceous plants is likely to be involved with the limited marginal spread of the forest. At the margin of forest with herbaceous communities a zone of less dense vegetation, about two metres wide occurs as a result of the forest influence. This seems to be related to root competition by beech trees limiting the grasses and other herbs, rather than shading. Within this zone beech seedlings become established at times, and thus the margin advances slowly. Moist summers are likely to be required for such establishment.

The establishment and survival of young beech trees within the forest seems to depend to some extent on the effects of temperature on the moisture regime. It was noticed that shady aspects, where young subcanopy beech trees are most abundant, have moist soil at all times, whereas at times in summer the upper layers of soil on sunny aspects were very dry. No quantitative data are available on this for Sugarloaf Bush, but Prestidge (1972), investigating sites on unforested shady and sunny aspects in nearby Chilton Valley showed that near-surface soil moisture conditions in some summer months on the sunny aspects would be limiting for plant growth. It may be inferred that, because of the cooler temperatures experienced in summer on shady aspects in Sugarloaf Bush, there will be less evaporation and both atmosphere and soil will be moister than on the sunny aspects. Study of the general hydrological regime of the forest is needed, including the overall spatial distribution of precipitation and groundwater.

Another factor affecting establishment and growth of beech trees within the forest is the light climate. Patches of young plants occur, often in extensive canopy gaps caused by fallen trees, but it is not known what relative effects are due to enhanced light or to improved nutrient conditions caused by lessened root competition in the canopy gaps. The light conditions appropriate for establishment and growth of beech trees have been examined in the study by Stevenson (1981) on the sunny aspect of Sugarloaf Bush. Wardle (1970) experimented with seedling germination of mountain beech under a range of light conditions (full light, about 64% full light, about 28% full light and almost complete darkness) over a range of altitudes and in several different soil conditions. The best germination (4% to 5%) was achieved in light shade (about 64% full light).

Nothing is yet known of the absolute amount of nutrients available for plant growth in the soils of Sugarloaf Bush, nor of the ecosystem nutrient budget. The aspect differences noted previously, with respect to temperature and moisture, may influence this through effects on litter decay and nutrient mineralization. Further studies are needed on these. Other biotic components of the system also need to be studied.

The temperature data presented here will provide useful background for future studies of other aspects of the ecology of Sugarloaf Bush. A more detailed numerical analysis of the data is planned and also the establishment of some more sophisticated climatic research equipment.

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TABLE 1. SITES AND INSTRUMENTATION FOR TEMPERATURE MEASUREMENTS

Run 1 2-12-1977 to 28-8-1979

+ thermometer present

Site	Approx. Altitude (m)	Aspect	Slope	Predominant Vegetation	Thermometer exposed at: Ground Level	20 cm Above Ground	1.5 m Above Ground	3 m Above Ground
1. East Saddle	870	NE	15°	*Leptospermum scoparium* scrub 3-4 m high over bare ground.	+			
2. Upper Eastern Slope	850	NE	15°	*Nothofagus solandri* closed canopy 10 m high.	+	+	+	+
3. East Valley	780	NE	15°	*Nothofagus solandri* closed canopy 18 m high.	+	+	+	+
4. Boulder Ridge	780	W	15°	*Nothofagus solandri* closed canopy 16 m high	+	+	+	+
6. Cass Hill	80	SE	22°	*Dracophyllum acerosum* scrub 1-2 m high in mosaic with short turf and bare ground.	+			
7. Upper Western Slope	820	SE	15°	*Nothofagus solandri* closed canopy 16 m high.	+	+	+	+
8. West Valley	780	SE	26°	*Nothofagus solandri* closed canopy 18 m high.	+	+	+	+

Run 2 29-8-1979 to 2-6-1982

					Soil -20 cm	1.5 m Above Ground	Ground Level Mature Open	Ground Level Mature Closed	Ground Level Pole	Ground Level Sapling
A. Cass Hill (Old Station 6)	as above				+	+				
B. West Treeline	830	SE	20°	Pole *Nothofagus solandri*, closed canopy 8 m high.	+	+				
C. Upper Western Slope (Old Station 7)	as above				+	+	+	+	+	+

D. West Mid Slope	800	SE	20°	*Nothofagus solandri* closed canopy 16 m high.	+	+				
E. West Valley (Old Station 8)	as above									
F. Boulder Ridge (Old Station 4)	as above				+	+				
G. East Valley (Old Station 3)	as above				+	+				
H. East Mid Slope	810	NE	20°	*Nothofagus solandri* closed canopy 16 m high.	+	+				
I Upper Eastern Slope (Old Station 2)	as above				+	+	+	+	+	+
J. East Treeline	860	NE	15°	Pole *Nothofagus solandri* closed canopy 8 m high.	+	+				
K East Saddle (Old Station 1)	as above				+	+				
L. Foweraker Spur	880	NW	22°	*Hebe brachysiphon* scrub 2 m high over grassland and bare ground.	+	+				
M. West Valley Mouth	700	S	20°	*Dracophyllum acerosum* scrub 1 m high over short turf, low shrubs and bare ground.	+	+				
N. East Valley Mouth	710	NW	22°	*Leptospermum scoparium* scrub 3-4 m high over bare ground and grassland.	+	+				